NITROGEN AND NOBLE GAS ISOTOPIC SIGNATURES IN BULK ALH84001 WITH CARBONATES. K. J. Mathew and K. Marti, Dept. of Chemistry 0317, University of California, San Diego, La Jolla, CA, 92093-0317,USA (e-mail: mkattath@ucsd.edu).

We have analyzed by stepwise heating a bulk sample of the Martian orthopyroxenite ALH84001 with documented carbonates in order to investigate trapped N and noble gas isotopic systematics in the carbonates relative to other phases. Earlier work on N in bulk ALH84001 and in density separates from ALH84001 [1, 2] revealed a light N component ($\delta^{15}N \leq -21$‰). Light N has also been observed in other meteorites of the SNC group (Chassigny, Lafayette, and Nakhla) [3].

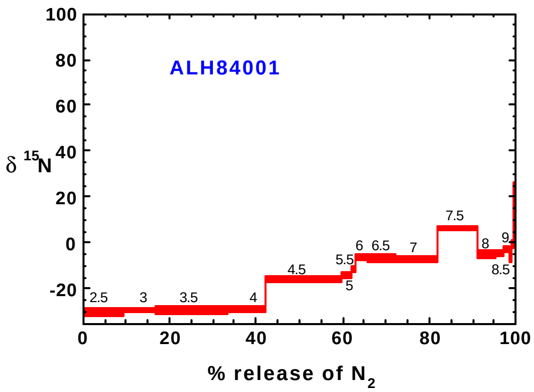

Fig. 1. Release systematics of $\delta^{15}N$ (‰) in bulk ALH84001 with carbonates. All temperature steps ≤400°C show consistent nitrogen signature of $\delta^{15}N$ =-30 ‰.The high temperature data are affected by spallation nitrogen.

The relationship between trapped N and noble gases in the carbonates to those in other mineral phases of the meteorite may provide clues to their history and provide constraints on the evolution of planet Mars. Xe in the bulk sample revealed the presence of two and possibly three distinct components. Such information would complement the chemical composition study of this meteorite [4, 5]. No physical separation of the carbonates was attempted to avoid contamination and since we planned to do a step-wise heating experiment on the sample to differentiate between the individual phases by their thermal decomposition. The samples were analyzed following standard procedures using a mass spectrometer operated in the static mode [2].

Fig. 1 shows the release systematics and the $\delta^{15}N$ signatures. The first four temperature extractions (≤ 400°C) gave consistent N signature of $\delta^{15}N$ = -30 ‰. This is the lightest N observed in a bulk sample of the SNC meteorites. The measured light N signature is in agreement with what is predicted for the Martian trapped N, based on a correlation of the $\delta^{15}N$ vs. atomic ratios of $^{40}Ar/^{14}N$ in the SNC meteorites [6], and with the inferred light end member composition based on an earlier analysis of two other ALH84001 bulk samples [1, 2]. It is interesting to note that the light nitrogen signature is comparable to nitrogen observed in E-chondrites and in aubrites [8]. Most of the N (> 99 %) is released at low temperatures (<1050°C) and the CO_2 release in these steps can be used as a monitor for carbonate decomposition. The N components released in the temperature range of 450°C to 1050°C show heavier isotopic signatures in the range $\delta^{15}N$ = +7 ‰ to -15 ‰. Since the release of CO_2 indicates the progress of carbonate decomposition, the release of carbonate nitrogen is constrained to the range of 300°C to 900°C. However, the measured signatures in the 300°C to 900°C extractions result from super-position of the light low-temperature N with N in the carbonates. This allows us to derive a lower limit for the N signature in the carbonate: $\delta^{15}N$ = +7 ‰, the maximum measured $\delta^{15}N$ at 750°C. This result shows that the carbonate has not exchanged isotopically with (heavy) N in the Martian atmosphere ($\delta^{15}N$ signature of 620 ‰ [7]).

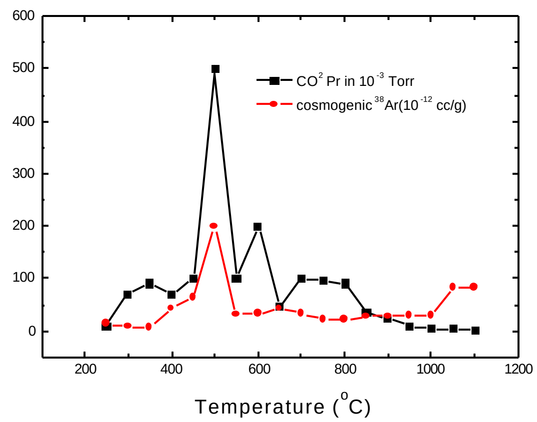

Fig. 2. Release systematics of CO_2 and of spallation ^{38}Ar from an ALH84001 bulk sample.

We also use a built-in monitor to assess the terrestrial contamination of the carbonates: spallation ^{38}Ar. The release of significant cosmogenic components of ^{38}Ar and ^{126}Xe in the low temperature steps is shown in Fig. 2. The CO_2 release tracks the release of $^{38}Ar_c$ due to the decomposition of $CaCO_3$ and $FeCO_3$. The simultaneous release of cosmogenic ^{38}Ar and ^{126}Xe in the low temperature steps suggest decomposition of Ca- and Ba- rich phases. Whether or not the observed cosmogenic effects are result of recent cosmic-ray exposure or of pre-irradiation on the Martian subsurface needs further consideration. Although several investigators have reported exposure ages of ~16Ma it has also been suggested, based on the nuclear track and cosmic-ray exposure age studies, that ALH84001 has a complex exposure history [9]. In the present study the total cosmogenic ^{38}Ar released in temperature steps up to 800°C is ~11%, comparable to 6% observed in another bulk ALH84001 sample by [10] and the spallation ^{126}Xe in the same range yielded ~20%. The release of spallation components at very low temperatures (Fig. 2) is somewhat surprising, but indicates the presence of interstitial phases or inclusions which react or decompose at temperatures below carbonate decomposition. These components also introduce a complication in the identification of the isotopic signatures of trapped Ar and Xe at the corresponding temperature steps.

The Xe and N components released at higher temperatures confirm the signatures reported in an earlier study [2]. Measured Xe components represent varying mixtures of a mass-fractionated atmospheric component and an indigenous solar-type component, as can be monitored by the $^{129}Xe/^{130}Xe$ ratios. Fission and spallation components are released at >1200°C and the latter component strongly affect the N isotopic signature.

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